NRMCA

What, Why & How?

Strength of In-Place Concrete

CONCRETE IN PRACTICE — CIP 10

WHAT is the Strength of In-Place Concrete?

Concrete structures are designed to carry dead and live loads during construction and in service. Samples of concrete are obtained during construction and standard ASTM procedures are used to measure the potential strength of the concrete as delivered. Cylinders are molded and cured at 60 to 80°F (17 to 27°C) for one day and then moist cured in the laboratory until broken in compression, normally at an age of 7 and 28 days. The in-place strength of concrete will not be equivalent to that measured on standard cylinders. Job practices for handling, placing, consolidation, and curing concrete in structures are relied upon to provide an adequate percentage of that potential strength in the structure. Structural design principles recognize this and the ACI Building Code, ACI 318, has a process of assuring the structural safety of the concrete construction.

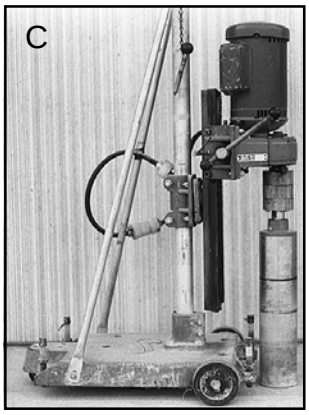
Means of measuring, estimating or comparing the strength of in-place concrete include: rebound hammer, penetration probe, pullouts, cast-in-place cylinders, tests of drilled cores, and load tests of the structural element.

Cores drilled from the structure are one of the means of evaluating whether the structural capacity of a concrete member is adequate and ACI 318 provides some guidance on this evaluation. Drilled cores test lower than *properly made and tested* standard molded 6 x 12 inch (150 x 300-mm) cylinders. This applies to all formed structural concrete. Exceptions may occur for cores from concrete cast against an absorptive subgrade or cores from lean, low strength mass concrete. The ACI Building Code recognizes that under current design practices, concrete construction can be considered structurally adequate if the average of three cores from the questionable region is equal to or exceeds 85 percent of specified strength, f'_c with no single core less than 75 percent of f'_c.

WHY Measure In-Place Strength?

Tests of in-place concrete may be needed when standard cylinder strengths are low and not in compliance with the specification as outlined in ACI 318. However, do not investigate in-place without first checking to be sure that: the concrete strengths actually failed to meet the specification provisions, low strengths are not attributable to faulty testing practices, or the specified strength is really needed. (See CIP-9 on *Low Concrete Cylinder Strength*) In many cases, the concrete can be accepted for the intended use without in-place strength testing.

There are many other situations that may require the investigation of in-place strength. These include: shore and form removal, post-tensioning, or early load application; investigation of damage due to freezing, fire, or adverse curing exposure; evaluation of older structures; and when a lower design strength concrete is placed in a member by mistake. When cores or other in-place tests fail to assure structural adequacy, additional curing of the structure may provide the necessary strength. This is particularly possible with concrete containing slow strength-gaining cement, fly ash, or slag.



A - Penetration Resistance Test (ASTM C 803)

B - Rebound Test (ASTM C 805)

C - Core Test (ASTM C 42)

HOW to Investigate In-Place Strength

If only one set of cylinders is low, often the question can be settled by comparing rebound hammer or probe results on concrete in areas represented by acceptable cylinder results. Where the possibility of low strength is such that large portions need to be investigated, a well-organized study will be needed. Establish a grid and obtain systematic readings including good and questionable areas. Tabulate the hammer or probe readings. If areas appear to be low, drill cores from both low and high areas. If the cores confirm the hammer or probe results, the need for extensive core tests is greatly reduced.

Core Strength, ASTM C 42 - If core drilling is necessary observe these precautions:

a. Test a minimum of 3 cores for each section of questionable concrete;

b. Obtain $3^1/_2$ in. (85 mm) minimum diameter cores. Obtain larger cores for concrete with over 1 in. (25.0 mm) size aggregate;

c. Try to obtain a length at least $1^1/_2$ times the diameter (L/D ratio);

d. Trim to remove steel provided the minimum $1^1/_2$ L/D ratio can be maintained;

e. Trim ends square with an automatic feed diamond saw;

f. When testing, keep cap thickness under 1/8 in. (3 mm);

g. Use high strength capping material; neoprene pad caps should not be used;

h. Check planeness of caps and bearing blocks;

i. Do not drill cores from the top layers of columns, slabs, walls, or footings, which will be 10 to 20 percent weaker than cores from the mid or lower portions; and

j. Test cores after drying for 7 days if the structure is dry in service; otherwise soak cores 40 hours prior to testing. Review the recommendations for conditioning cores in current versions of ACI 318 and ASTM C 42.

Probe Penetration Resistance, ASTM C 803 - Probes driven into concrete can be used to study variations in concrete quality:

a. Different size probes or a change in driving force may be necessary for large differences in strength or unit weight;

b. Accurate measurement of the exposed length of the probe is required;

c. Probes should be spaced at least 7 in. apart and not be close to the edge of the concrete;

d. Probes not firmly embedded in the concrete should be rejected; and

e. Develop a strength calibration curve for the materials and conditions under investigation.

Rebound Hammer, ASTM C 805 - Observe these precautions:

a. Wet all surfaces for several hours or overnight because drying affects rebound number;

b. Don't compare readings on concrete cast against different form materials, concrete of varying moisture content, readings from different impact directions, on members of different mass, or results using different hammers;

c. Don't grind off the surface unless it is soft, finished or textured;

d. Test structural slabs from the bottom; and

e. Do not test frozen concrete.

Advance Planning - When it is known in advance that in-place testing is required, such as for shore and form removal, other methods can be considered such as: cast-in-place, push-out cylinders and pullout strength measuring techniques covered by ASTM C 873 and C 900.

References

1. *In-Place Methods to Estimate Concrete Strength*, ACI 228.1R, American Concrete Institute, Farmington Hills, MI.
2. *Nondestructive Tests*, V.M. Malhotra, Chapter 30 in ASTM STP 169C, American Society for Testing and Materials, West Conshohocken, PA.
3. *Guide to Nondestructive Testing of Concrete*, G.I. Crawford, Report FHWA-SA-97-105, Sept. 1997, Federal Highway Administration, Washington, DC.
4. *In-Place Strength Evaluation - A Recommended Practice*, NRMCA Publication 133, NRMCA, Silver Spring, MD.
5. *Understanding Concrete Core Testing*, Bruce A. Suprenant, NRMCA Publication 185, NRMCA, Silver Spring, MD.
6. ASTM C 31, C 39, C 42, C 805, C 803, C 873, C 900, ASTM Book of Standards, Vol. 04.02, American Society for Testing and Materials, West Conshohocken, PA
7. *Building Code Requirements for Structural Concrete*, ACI 318, American Concrete Institute, Farmington Hills, MI.

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